On Topological Structures of Flows and Magnetic Fields in the Sun and Heliosphere

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Abstract

Topological structures of flows and magnetic fields play critical role in the generation of solar activity and its transport to the interplanetary space. Thus one of the key sources of the solar dynamo is the kinetic helicity which characterizes the correlation between the velocity and vorticity of flows inside the convection zone. Another distinguished quantity is the magnetic helicity that determines the dynamics of the magnetic flux emerging to the solar surface and formation of coronal mass ejections.

Because magnetic helicity is conserved, the production and time evolution of helicity is due to its redistribution in space and in scale. Thus, the conservation of magnetic helicity implies that ejection of helicity into the solar wind is accompanied by production of an equal amount of helicity of opposite sign left at the Sun. The production of large-scale magnetic helicity by a mean-field dynamo is accompanied by a cascaded of helicity of opposite sign to the smaller scales. The helicity produced by the dynamo has opposite signs in the northern and southern solar hemispheres.

A study of the evolution of magnetic helicity produced by mean-field dynamos indicates that the helicity of each hemisphere of the Sun oscillates about a mean with the period of the solar cycle (11 years). The magnetic helicity in a given hemisphere does not change sign from one 11 year period to the next. A rigidly rotating Sun creates a stationary helical configuration in the solar wind (the Parker spiral). Solar differential rotation and emerging flux produce an excess of helicity. It is suggested that this helicity excess is carried out of the Sun by solar mass ejections causing an overwinding of the Parker spiral, which varies with the solar cycle.